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Coronal and Heliospheric Model Development in MS-FLUKSS

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Outline

1. Coronal models based on characteristic boundary conditions

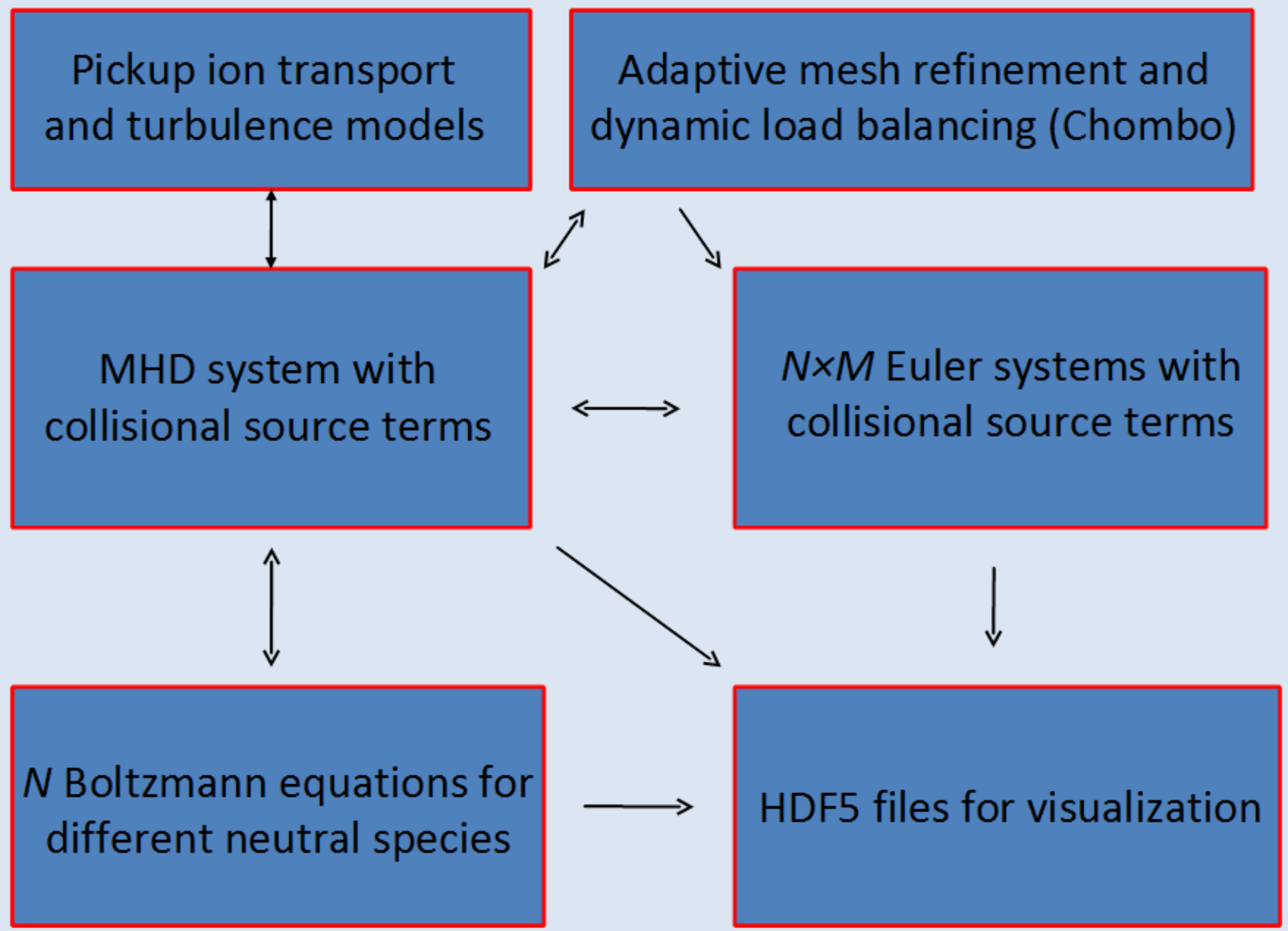
2. CMEs

3. Inner heliospheric model

4. Extension to remote planets/outer heliosphere

5. Plans related to CCMC

The Structure of the Multi-Scale Fluid-Kinetic Simulations Suite



Data-driven solar wind models: Research approach.

To attack the outlined problem efficiently, we propose an approach that is based on synergy of time dependent, 3D, numerical simulations, and observational data analysis.

Synchronic vector magnetograms and horizontal velocity data.

We use SDO/HMI vector magnetograms with 720 s cadence to get 2 components of the magnetic field vector. DAVE4VM method (Schuck, 2008; Liu et al., 2013) is applied to compute the horizontal velocity data in the vicinity of active regions.

Away from the active regions, the surface boundary conditions – the longitudinal and latitudinal flow velocities, and the radial and longitudinal magnetic field components – are produced in near real time by assimilating vector magnetic field data from SDO/HMI into our surface flux transport code, the Advective Flux Transport (AFT) code (Hathaway & Rightmire, 2010, 2011). This approach can eventually be extended to active regions as well.

Results from the Adaptive Flux Code

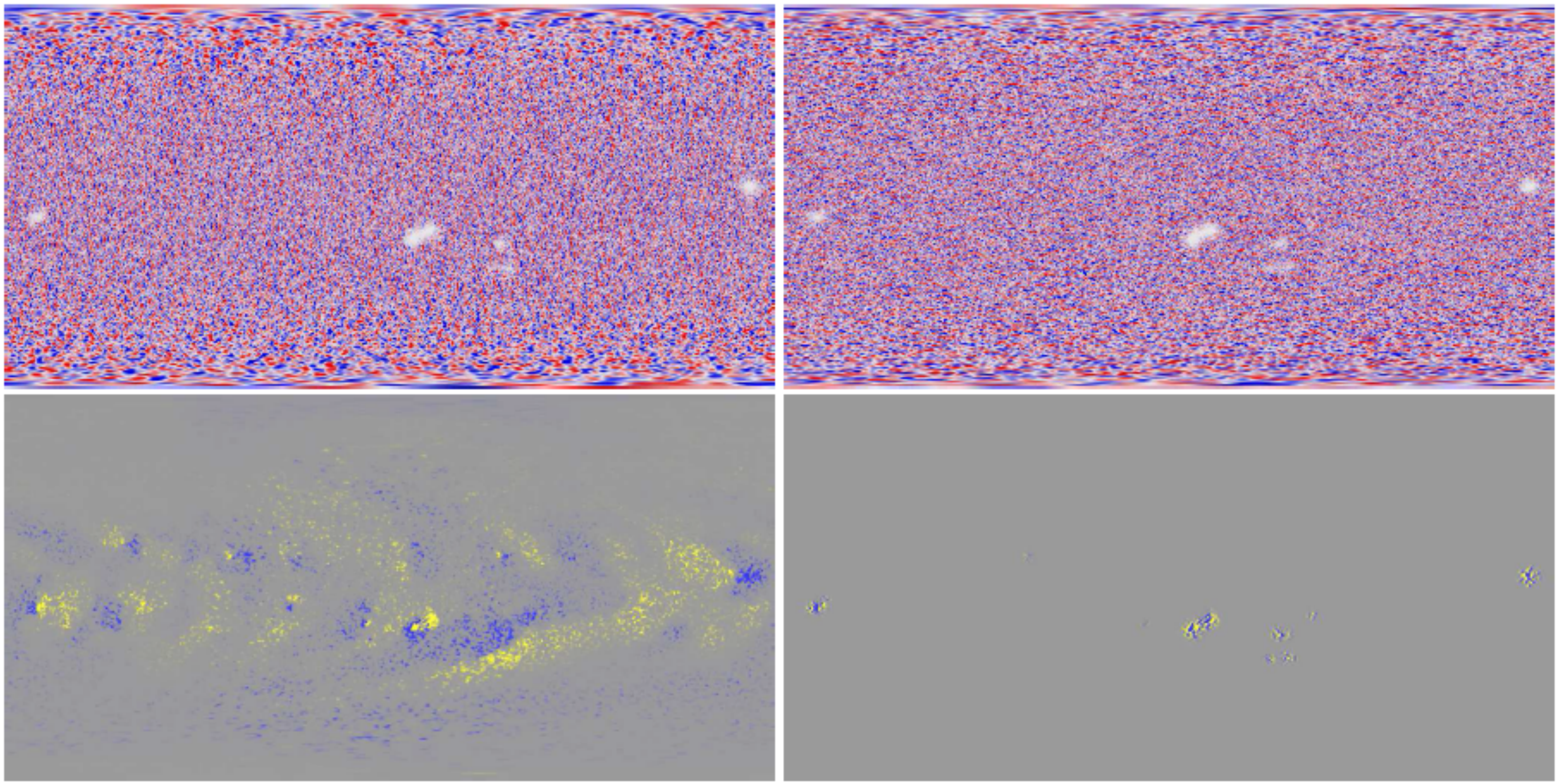


Figure 1: Boundary conditions for 03/15/2015 at 00:00:00. Upper left panel: longitudinal flow velocity; upper right panel: latitudinal flow velocity; bottom left panel: radial magnetic field; and bottom right panel: longitudinal magnetic field. The flow velocities are dominated by the convective flows with a typical range of ± 1500 m/s. The active region quenching is indicated by the fuzzy white patches.

Results obtained with DAVE4VM

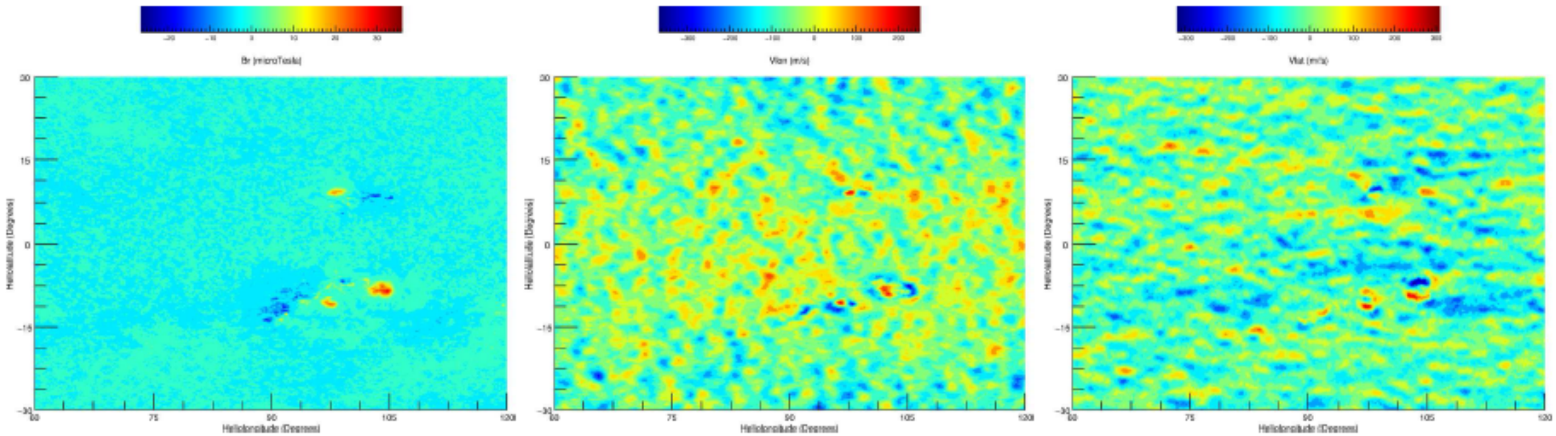
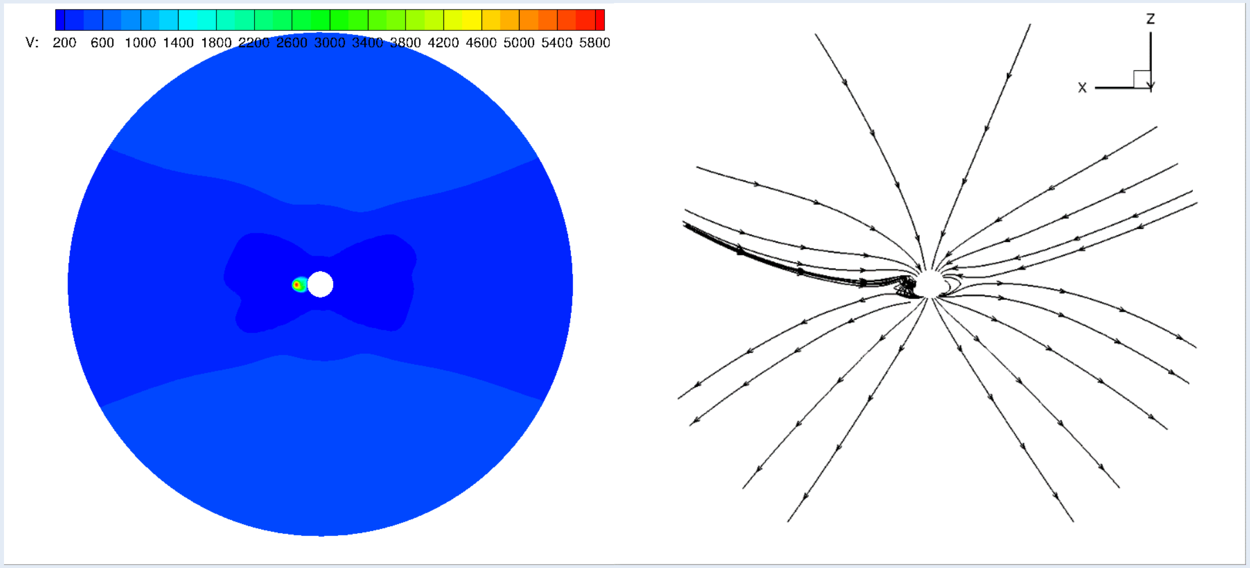
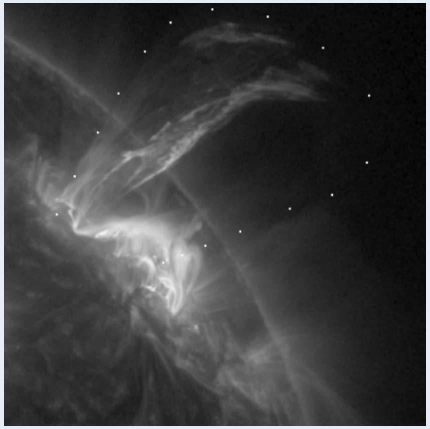


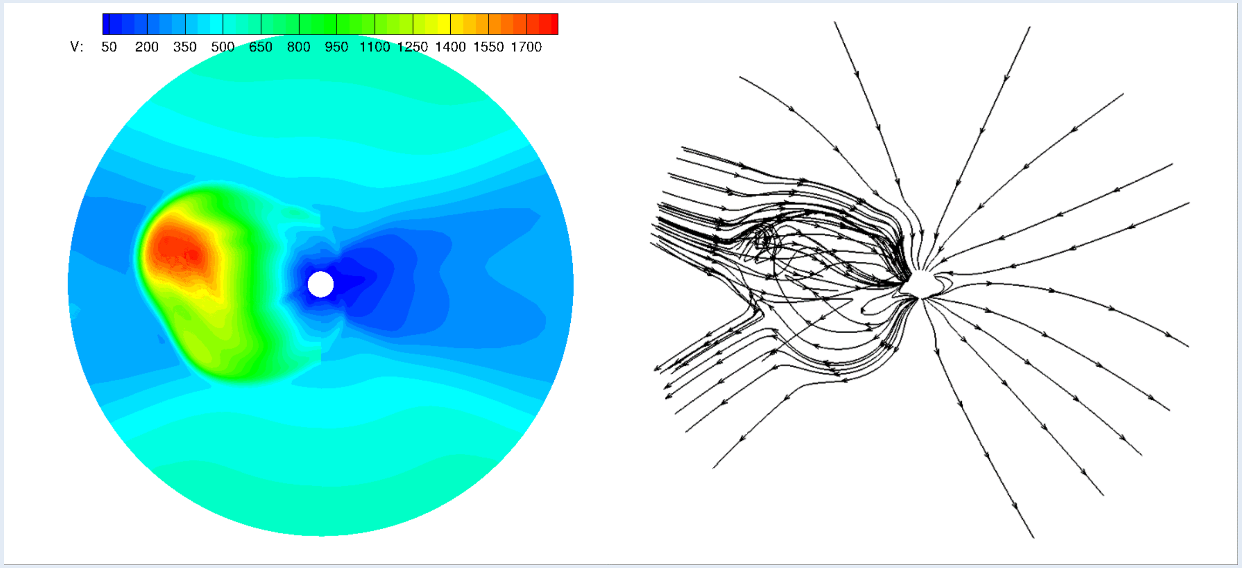
Figure 2: An example of a CR2145 synoptic map for the radial magnetic field component zoomed to an active region (the left panel) and the longitudinal and latitudinal velocity components derived from the vector map using DAVE4VM (the middle and right panels, respectively).

Although we do not have magnetic field observations of the Sun's far side, we do have EUV images from STEREO. Such images can be used to provide fairly precise estimates of the total unsigned flux in an active region on the far side. If a new active region emerges, or an old active region increases in size, new flux (with balanced polarities) is added at the observed location on the far side.

Data-constrained Model for Coronal Mass Ejections Using Graduated Cylindrical Shell Method (Singh et al., 2018)

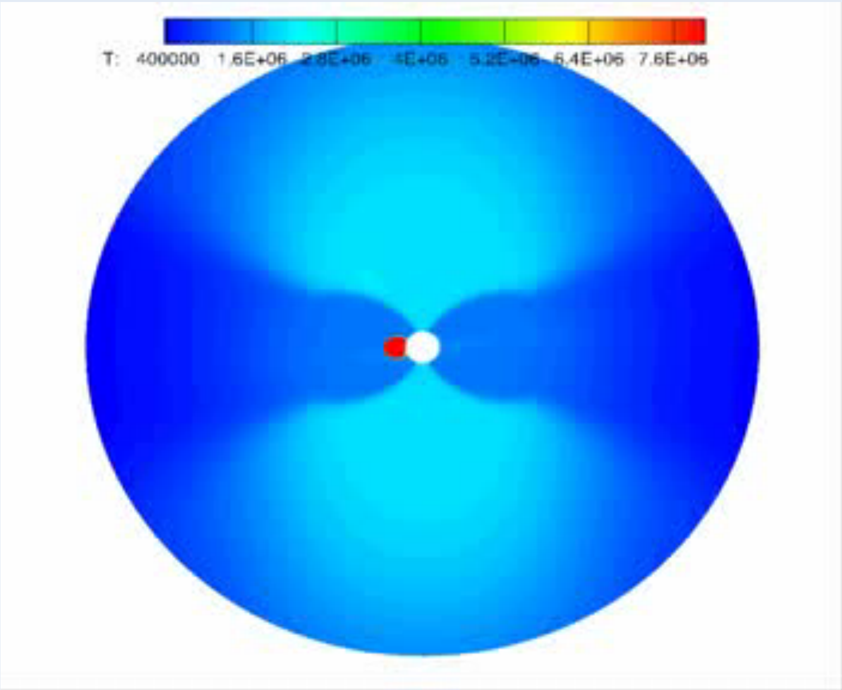


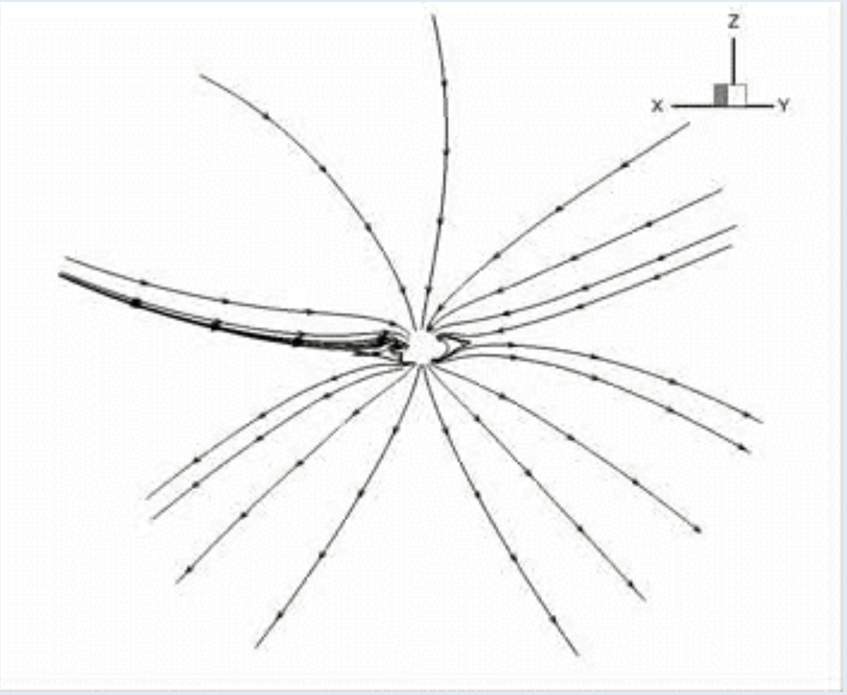




(Above) Solar eruption observed on 7 March 2011 by the Atmospheric Imaging Assembly (AIA) in 13.1 nm wavelength.

(Right) Simulated velocity and magnetic field lines 1 min (top panel) and 1 hr (bottom panel) after the eruption.





Animations of the SW temperature and magnetic field lines as the CME propagates towards Earth.

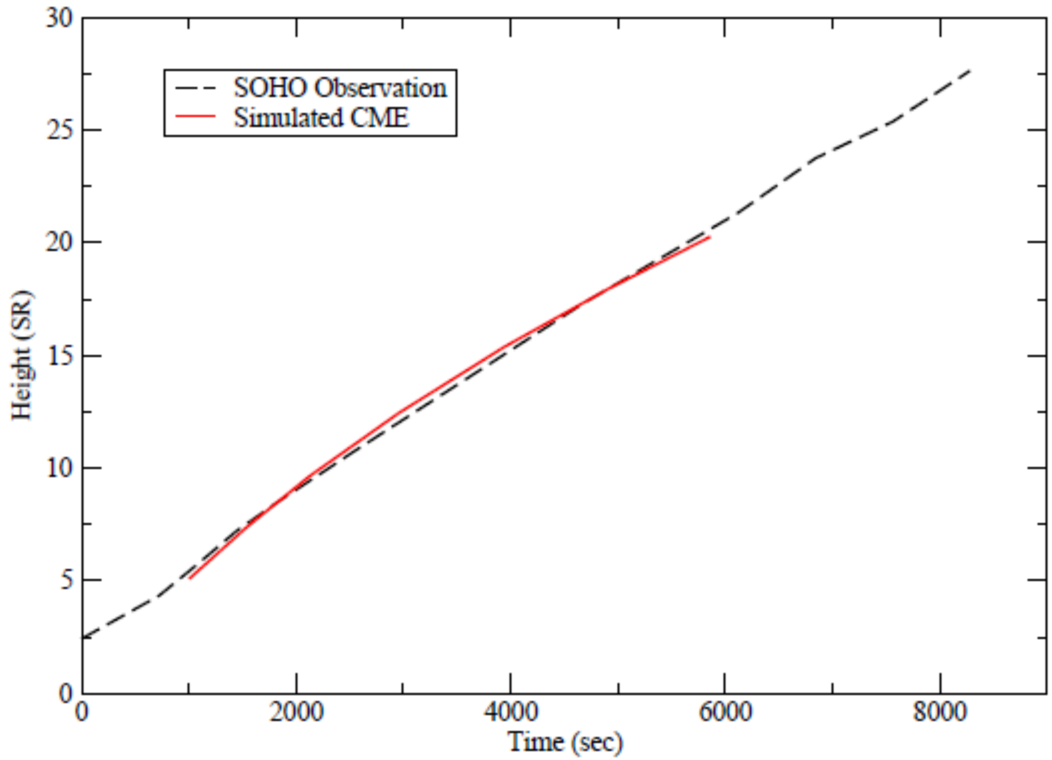
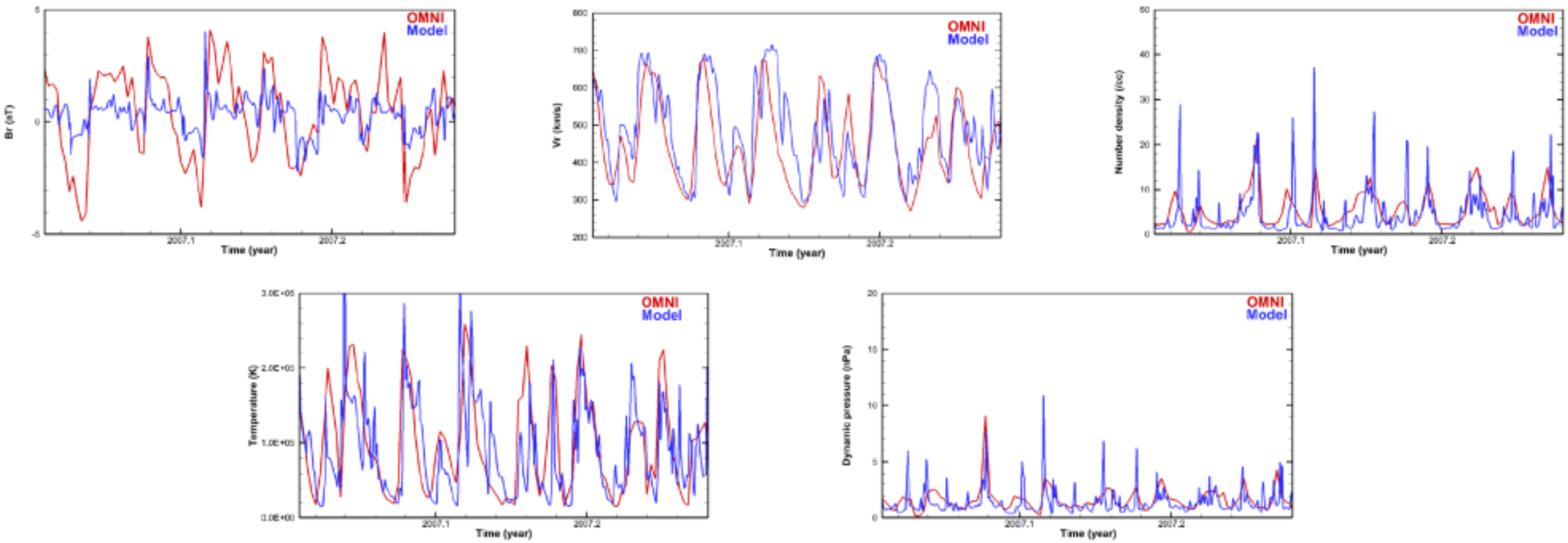


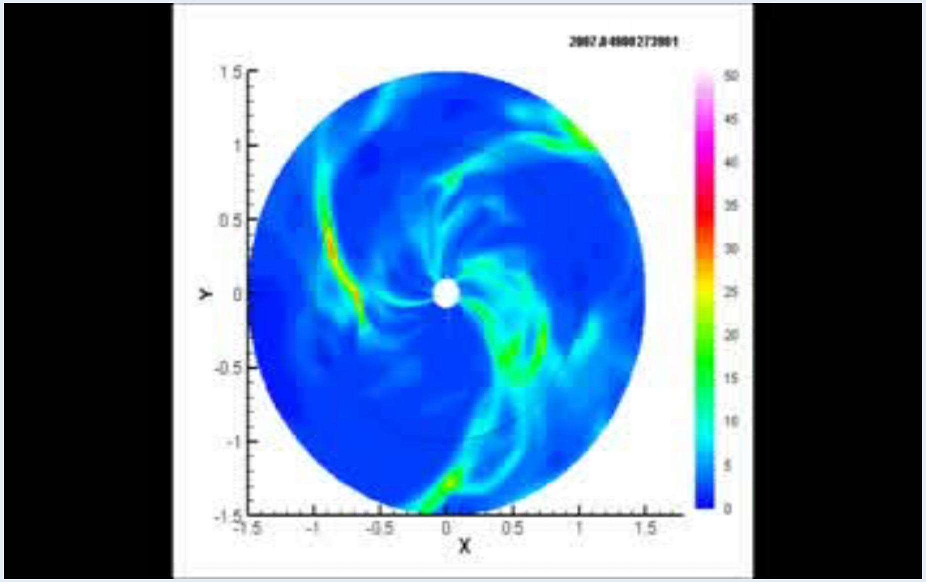
Figure 10. Comparison of height vs.time graphs between LASCO/C3 observations and simulation results.

MS-FLUKSS coupled with Wang-Sheeley-Arge (WSA) coronal model

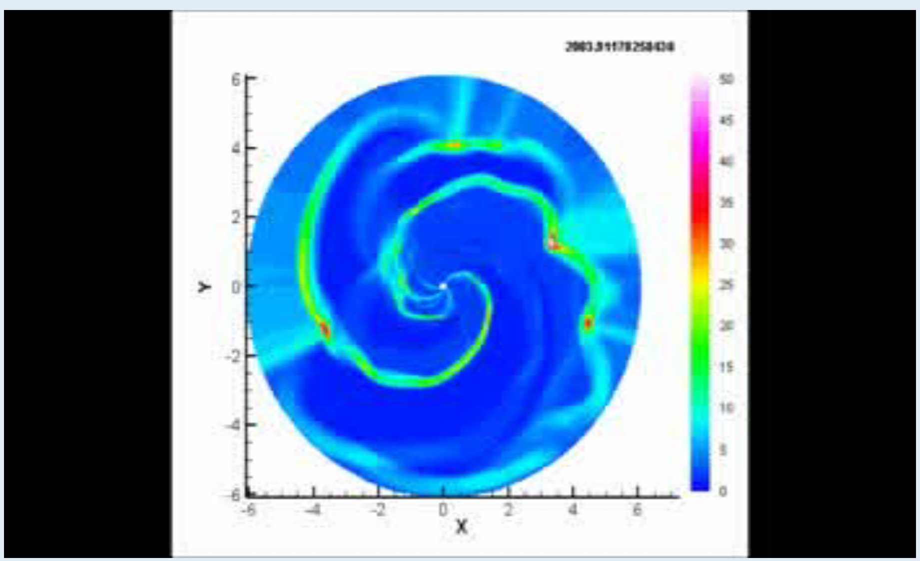


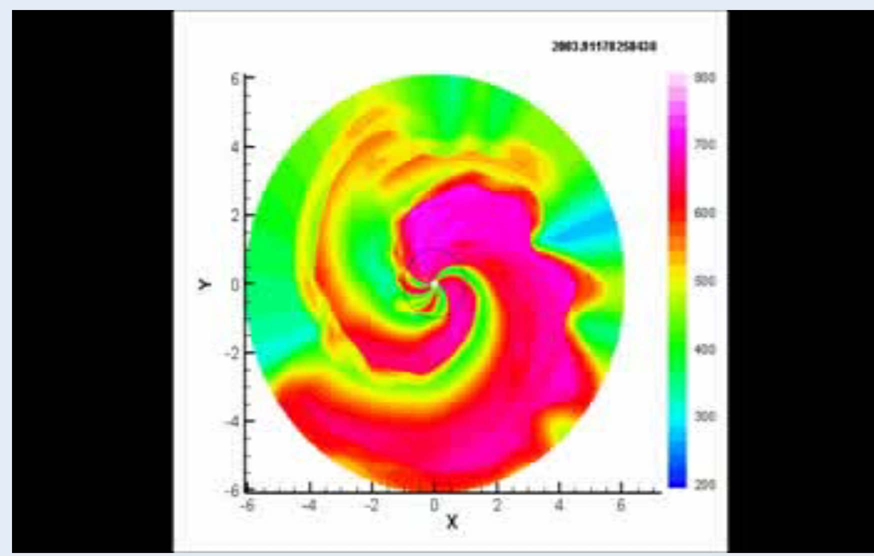
. MS-FLUKSS compared with OMNI data. Time-dependent boundary conditions from the ADAPT-WSA model (Arge et al. 2003, 2004, 2005, 2010, 2012, 2013) using NSO/GONG magnetograms

WSA/ADAPT provides Br and V; we further derive density and temperature at 21.5 Rs using my Ulysses formulae for 2003-2004 and 2007, or Heather Elliott's OMNI formulae for 2012. [Simulations of Tae Kim.]

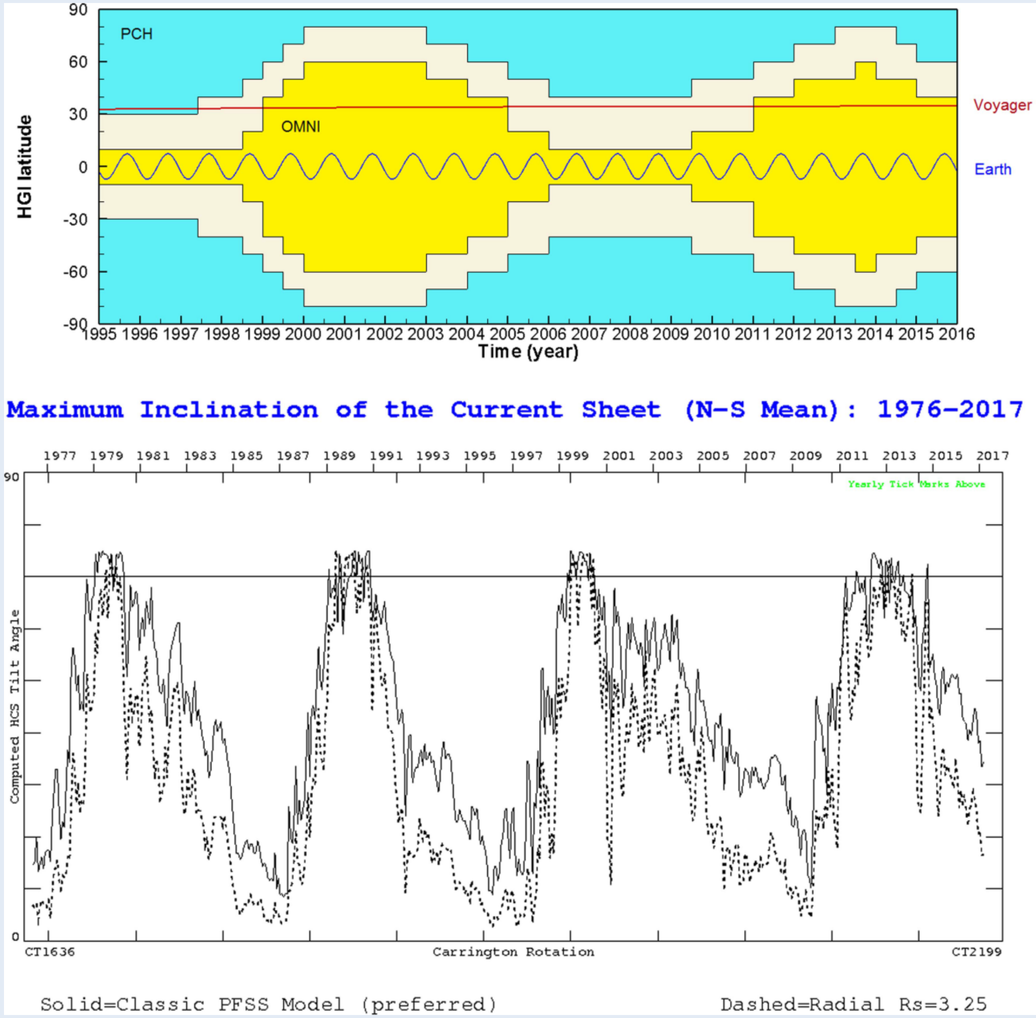


Density and radial velocity components in the simulation driven by the WSA/ADAPT model.

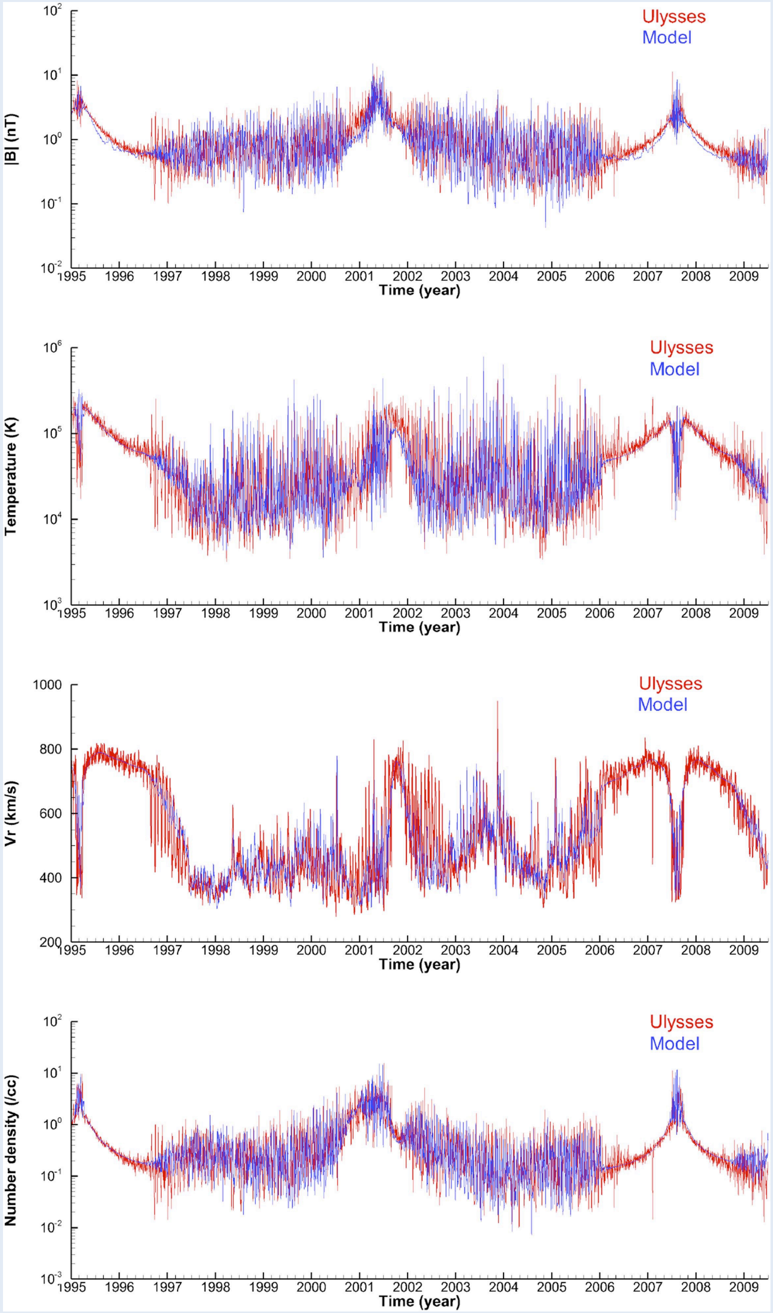




A new, data-driven model of the SW-LISM interaction (Kim et al., 2016)

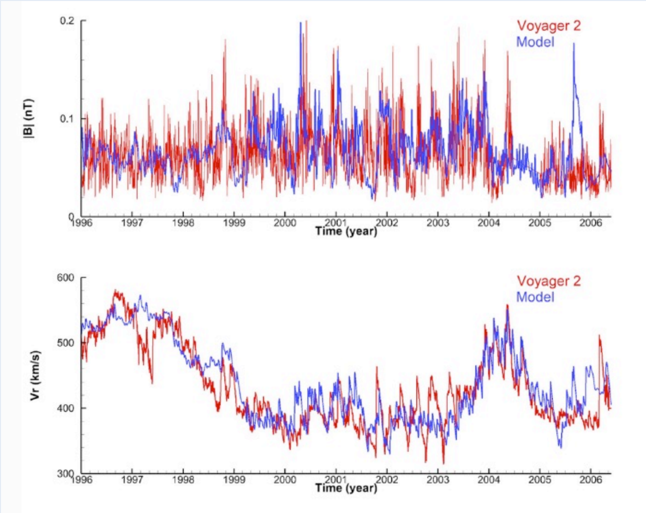


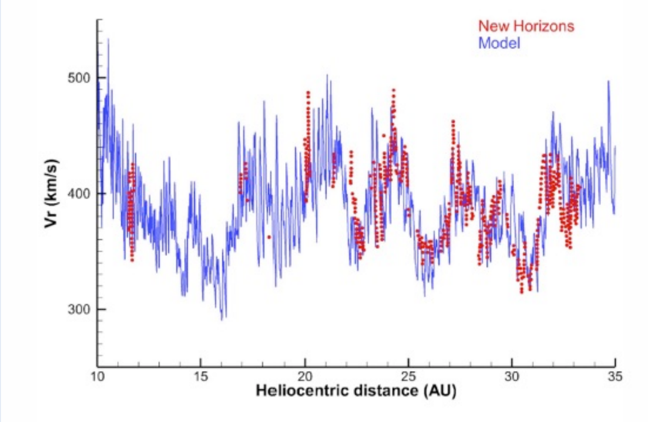
Constructing the boundary conditions: Top: a diagram showing the temporal variation of the latitudinal extents of the PCHs (light blue) and OMNI data (yellow) at 1 au. Also shown are the heliographic latitudes of Earth (blue) and Voyager 1 (red). Bottom: average HCS tilt shown as a function of time (courtesy of WSO).

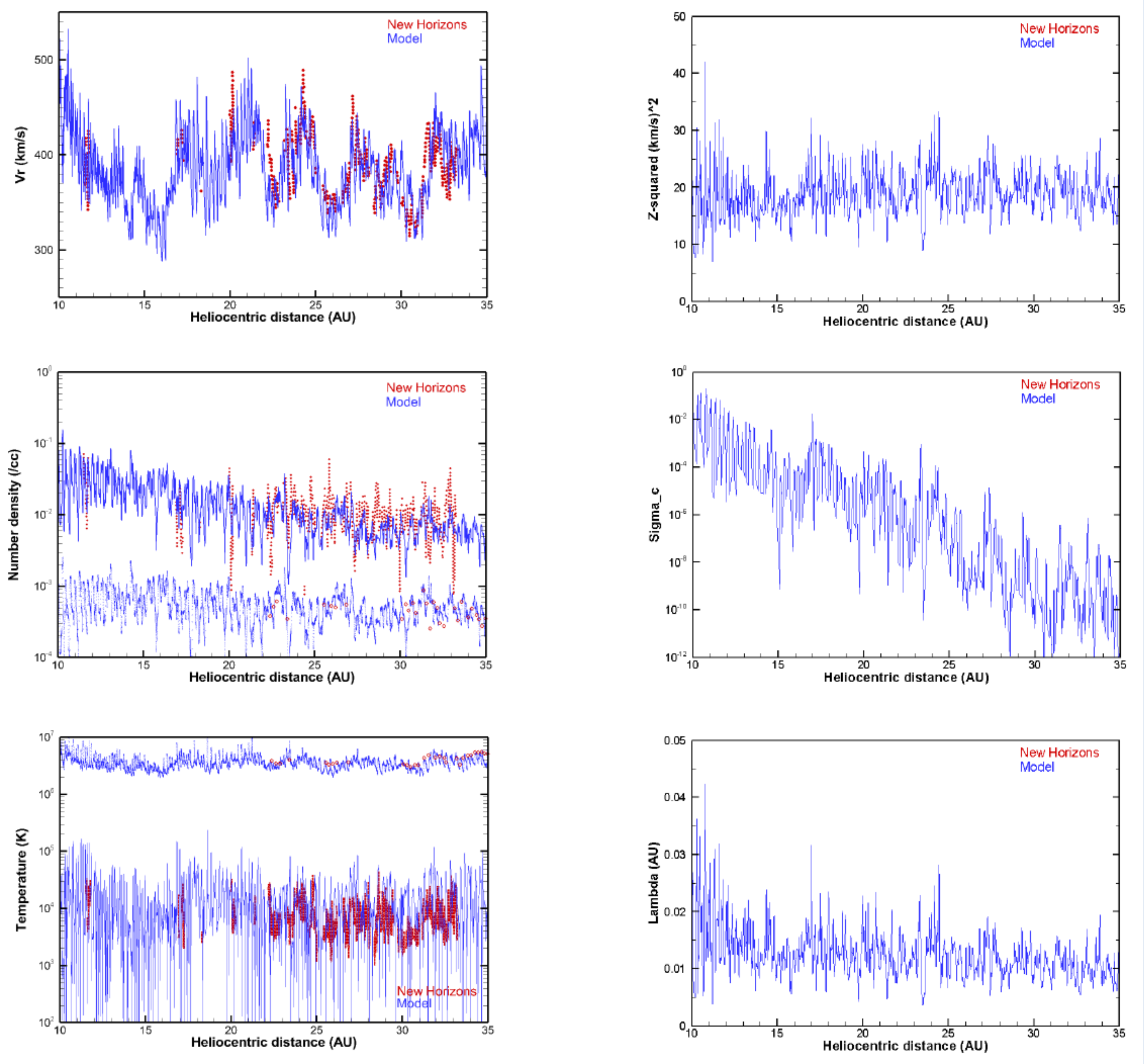


(*Left panel*) Comparison of our simulations with the SW measurements along the *Ulysses* trajectory.
(*Bottom panels*) Comparison with Voyager 2 and New Horizons observations.

From Kim et al. (2016).





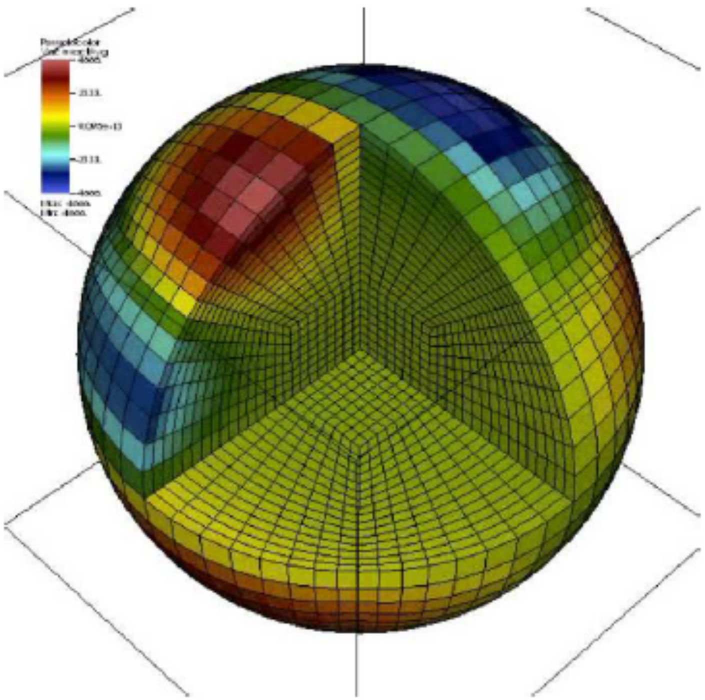


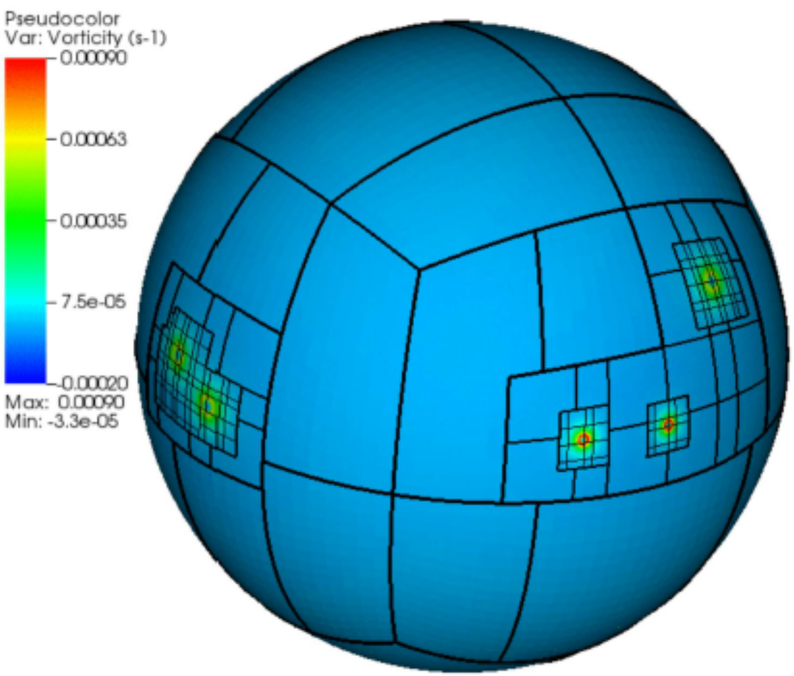
Model solar wind radial velocity, number density, and temperature are compared with NH/SWAP observations (Elliott et al. 2016) in the left column. Model interstellar pickup proton density and temperature are marked by open circles and compared with NH/SWAP observations (McComas et al. 2017). Turbulence parameters such as Z^2 (total turbulent energy density in turbulent magnetic and velocity fluctuations), σ_c (cross helicity), and λ (correlation length) are shown in the right column.

Work in progress

1. The 4th order of accuracy in space and time on adaptive grids

2. Mapped grids, e.g., cubed spheres.





CCMC Related Plans

1. We regularly provide simulation data along New Horizons trajectory and remote planets, where PUIs are of importance.
2. We will submit our code to CCMC that would make it possible to perform data driven, AMR simulations beyond the R-hyperbolic surface surrounding the Sun.


ASTRONUM 2018
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